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The Value of Well-Being

Advancing Urban Blue Infrastructure with Holistic Metrics

By: Lisa Marie White - Portland State University 2014

An undergraduate honors thesis submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science in University Honors and Social Science.

Thesis Advisers Olyssa Starry & Marissa Matsler

ABSTRACT

The design of urban infrastructure has emerging, documented impacts on the environment, local economy, and public well-being, yet conventional design and policy goals fail to account for these emergent properties. These impacts also lack consistent quantifiable metrics and classification in the realm of city planning. Without adequately holistic cost-benefit analyses, the true value of infrastructure projects fails to be ascertained, preventing consideration of design that provides additional benefits not yet incorporated into city policy and metrics. With more people living in cities than ever before, the built environment of cities has become an increasingly important area of study, and the creation and replacement of aging infrastructure presents an unprecedented opportunity to innovate and rethink best practices.

Does urban water infrastructure stand to benefit, in design and paradigm advancement, from more holistic economic assessment that incorporates the financial value of potential human well-being benefits? This paper explores the motivational and physical evolution of urban water infrastructure, including advancements in ecologically conscious, low-impact designs, and how the value of projects has largely been based on narrow metrics of measurable engineering utility, like quantification of reduced storm water flows. One missing evaluative consideration, human well-being, is then discussed, including its development and quantification in urban areas. Stream daylighting, a relatively new and difficult to classify storm-water management design, is explored as an example of promising new practices that would benefit from holistic cost-benefit analyses, and that cities may forgo when emergent properties are absent from metrics equating value. This paper argues that incorporating the economic value of human well-being when assessing the cost and benefit of water management infrastructure stands to substantiate more

sustainable and innovative designs, opening urban water infrastructure to further evolution that may better serve the populace and ecology for which it is designed.

DEFINING INFRASTRUCTURE

The current configuration of urban water management structures arose from historical contexts and motivations that standardized traditional sewer techniques (Melosi, 2000). One of the most recent advancements in design has been a shift from primarily grey infrastructure to the incorporation of green and Low Impact Design (LID) infrastructure designs (Mell, 2010). Before delving into historical context, definitions and delineation of the classifications of water infrastructure are provided for clarity. And while these terms are often interchangeable and can vary widely in meaning, for the uses of this paper, we will refer to the definitions described in this section.

Blue Infrastructure has heretofore encompassed engineering solutions specific to the management of urban rain, storm, drinking, and wastewater (Andoh, 2011). Urban water management is currently defined as “the fields of water supply, urban drainage, wastewater treatment and sludge handling” within urban centers, all of which are impacted by density, impervious surfaces, and existing landscape attributes (Larsen, 1997, p. 1). Many of the techniques sub classified as “blue infrastructure” fall into the broader category of Grey Infrastructure, which refers to man-made, often concrete systems designed to provide access to water while separating people and the city from undesirables, such as sewage and storm water. These designs generally use concrete or other hard material pipes in attempts to prevent flooding while removing potentially hazardous human waste from population centers as directly and therefore quickly as possible (Andoh, 2011). Green Infrastructure usually refers to the

utilization of ecological processes, such as water filtration provided by wetlands, and to address management of the urban environment with more sustainable, less resource- and construction-intensive means (Andoh, 2011). The term “green” is usually applied to infrastructure like urban trees and parks that are managed and designed separately from blue infrastructure, but as Low Impact Design (LID) continues to enter the mainstream of city planning, designs and policy are often blurring the separation of these classifications, like using plants to manage stormwater ala, for example, bioswales in Portland, OR.

LID is a relatively new classification of infrastructure that advances ecologically conscious green designs already implemented by cities around the globe. LIDs are defined as management techniques that seek to cause as little disruption in local hydrological and ecological processes as possible during development (Dietz, 2007). The designs are informed by, and seek symbiosis with, local ecology. This proves a vast departure from grey approaches that dominate landscapes solely to serve human desires and needs.

Infrastructure definitions and classifications are continuing to change over time. As populations continue to concentrate and expand in urban centers worldwide, urban planning and infrastructure paradigms are adapting to changing demands, landscapes, social preference, and political paradigms (McMichael, 2000). Through these changing practices and demands, the emergence of an altered definition of urban green infrastructure has come to the forefront, with green infrastructure now incorporating parks and other natural “attractions” designed for the enjoyment and well-being of the citizenry, creating a space for the sociological, psychological, and health implications of the built environment (McMichael, 2000). While some studies have incorporated a more holistic understanding of water management Infrastructure, such as Volker’s and Kistemann’s consideration of blue therapeutic landscapes in Cologne and Dusseldorf

in Germany, the concept of water systems impacting human well-being beyond waterborne illness prevention is still in its infancy (Volker & Kistemann, 2013).

INFRASTRUCTURE IN CONTEXT: THE HISTORIC PERSPECTIVE

In cities globally, water management infrastructure lagged behind the implementation of transportation, housing, and other essential forms of infrastructure, only appearing after the mid eighteenth century in Europe and the early nineteenth century in the Americas, often hundreds of years after the cities they served were thriving metropolises (Melosi, 2000). The motivation for the hierarchy of advancements in urban water systems was inextricably tied to private interest. Where money and power potential appear, so does interest in advancement (Basolo, 2000; Melosi, 2000; Tarr, 1996; Elkin, 1987).

Unlike commerce and the transportation of goods or even the supplying of piped water to households, waste and storm water management were originally the domain of the individual. City waterworks that provided water to residents, ending the need for fetching water from wells and rivers, were originally funded and run by the private sector (Melosi, 2000). Seeing potential for investment return through citizen utilization of the system for a fee, the private sector, not city government, ultimately drove the revolution of water supply systems. Storm and waste water, however, did not appear to provide the same potential profit for industry, and with limited understandings of the health and cost implications to cities for establishing and maintaining sewers, waste and storm water systems failed to gather a similar implementation priority (Tarr, 1996; Melosi, 2000). Though most urban households in the mid to late nineteenth century had obtained running water, individually waste disposal via privy vaults and cess pools remained the norm, and storm water still ran directly into the streets (Tarr, 1996; Melosi, 2000). The increased

ease of access to water increased per capita water usage, in turn increasing wastewater in need of disposal. These increased loads led to flooding and sewage pooling throughout urban centers as obsolete technology and lack of consideration butted up against more modern systems (Tarr, 1996; Melosi, 2000). In some ways, this “afterthought” mentality relating to storm and wastewater infrastructure has carried through to today, with fundamental environmental advancements made in housing, open space, and transportation design that continue to exceed those in blue infrastructure.

The primary motivational force behind the creation of sewer systems, unlike the private industry benefits and density related fire concerns that spurred the evolution of tap water, were untenable overflows of sewer and storm water coupled with spreading epidemics (Melosi, 2000). At this time, germ theory, or the scientific study of bacteria and viruses as vectors for disease, and advancements in understandings of water pollutants were yet to be developed, and human health in its most rudimentary understandings (e.g. basic survival), much like water infrastructure itself, remained an afterthought in city management and infrastructure of the time (Melosi, 2000). But as concepts of “bad” water and air leading to illness grew and waste management on the individual level became incompatible with denser urban cores, cities were forced to step into managerial and construction roles left unaddressed by private industry. The unpopularity of governmental intervention and accompanying taxation, originally cemented into the American mentality around the time of the Revolution, were detrimental in raising public support despite minimal protest of similar fees from private industry for water supply (Wills, 1999; Melosi, 2000). These undertones of government distrust and knee-jerk distaste for taxation appear to have carried on into modern times.

Beyond a comparatively stunted enactment of infrastructure, the study of LID has been similarly neglected. Green infrastructure outside of water management has advanced from broad definition to specific categories, and accompanying researching parsing human health and well-being impacts affected by individual attributes within each detailed green category are being explored, while none such specific literature exists for LID infrastructure (Jorgensen & Gobster, 2010). For example, the value of ecosystem services provided by urban trees, from water treatment to air purification to reductions in crime, has been studied at length, but only a handful of studies on an emerging LID infrastructure design known as stream daylighting exist, and none calculate the full benefits of the design (McPherson & Rowntree, 1993; Nowak, 1993; McPherson et al, 1997; Nowak & Crane, 2002; Pretty et al, 2005; Smith, 2007; Sander et al, 2010; Wild et al, 2011; Trice, 2013).

EMERGING PARADIGMS, LIMITATIONS, & COST SAVINGS: MODERN LID INFRASTRUCTURE IN PRACTICE

What we invest time and resources in, like funding, study, and trial through implementation, we denote as hierarchically more valuable, giving those things priority in consideration and enactment (Arrow, 1963). Neither an encompassing measurement of human well-being nor ecologically inspired water management practices have received much attention, reinforcing their seemingly lesser status in city planning. There have been a handful of successful implementation examples, some of which are discussed in this section, and the cost savings of accouterment “green” water features, like permeable pavement, show promise (Fjell, 2007). But lack of research and non-existent policy and classification continue to hold back many of these practices, particularly in the USA (Petts et al, 2006).

In places where innovative LID has been implemented, cities have seen accompanying cost savings upwards of \$329 per square in comparison to conventional design, longer infrastructure lifespans, 3-6 times the water sequestration effectiveness per \$1000 invested in LID storm water management versus conventional methods, and improved urban livability accompanying greener more appealing landscapes (Fjell, 2007; Foster et al, 2011). With more designs being implemented and subsequent benefits and savings now quantifiable through primary research, some scholars are already making the economic case for LID, however most of this substantiation is limited to “avoided costs” rather than more comprehensive consideration of added benefit (Moffa, 1997; Fjell, 2007; Smith, 2007; Wild et al, 2011; Foster et al, 2011; Trice, 2013).

Despite a lagging evolution, LID is increasingly visible in cities around the world. In Curitiba, Brazil, flood mitigation and storm water management were addressed via the recreation of wetlands alongside an inner city park, with more expensive options, such as creation of a concrete culvert, were ultimately rejected due to cost (Tucci, 2004). The unexpected benefits to the city, with citizens pleased by access to a new park and increases in nearby property values adding to property tax revenue, added value to the successful project (Tucci, 2004).

Following large and damaging storms in New York City, NY, there have been proposals for storm surge mitigation achieved through natural buffer restoration, including rebuilding historic wetlands and sand dunes (Fountain, 2013). In Zurich, Switzerland, and parts of Germany, stream daylighting, or unearthing natural streams that have been diverted and paved over in city centers, is increasingly invested in as a natural solution to combined sewer overflows (CSO's), or sewage overflow resulting from excessive storm water loads on existing wastewater pipes (Conradin & Buchli, 2005; Volker & Kistemann, 2013). On a smaller scale, the building of Tanner Springs park

in Portland, OR created habitat, storm water retention, and open green space for the public by replicating the water sequestration of a wetland ala biomimicry (City of Portland, 2013).

All of these projects exemplify the blurring of lines in infrastructure classification, incorporating LID and blue infrastructure in designs mostly considered “green” infrastructure (Wise, 2008). Muddling of LID and green in the literature, with LID usually discussed interchangeably with green despite separate policy classifications and funding streams, detracts from potential development of water specific designs, leaving LID functions and design virtually the same as in previous iterations, just with increased foliage. An example of technically traditional water management practices reframed as “green” and/or LID is the Big Pipe project in Portland, where bioswales, or storm water retention planters, were used to reduce the size of a replacement combined sewer pipe (Law, 2014). The cost of the project was reduced by using a smaller pipe, with reduced flows likely influenced by the planters, but beyond concrete retention basins with added hydrophilic greenery, this “forward thinking” water management project still relied on the use of a traditional, concrete pipe as its primary design (Law, 2014). Today’s conventional water infrastructure goals appear nearly the same as previous generations, with metrics for evaluating them still relying solely on peak storm water flows, pollutant concentration removal efficiencies, pollutant loads, and other measures of mitigation and engineering utility (EPA, 2004; Lenhart & Hunt, 2011). Meanwhile, when innovative LID is used, the projects are not clearly classified and emergent properties influenced by the designs, like the benefits to citizens provided by the park in Curitiba, Brazil, and the subsequent financial benefit of healthier places and people to the city, remain mostly absent from cost-benefit understandings of these projects. When they are incorporated, they aren’t clearly discussed, with the terms

“cultural” and “community” benefits referred to with inconsistent definitions (Wise, 2008; Berkooz, 2011).

So while there are case studies of successful practices in ecologically inspired storm water management, there remains a general failure to both provide specific classification and to evaluate designs holistically by considering well-being as an emergent property (Debo & Reese, 2003; Davis, 2005; Elliot & Trowsdale, 2007; Dietz, 2007; Williams & Wise, 2007; Roon, 2007).

AN ESSENTIAL AND MISSING EVALUATIVE LINK: WELL-BEING

Human well-being and the built environment are inextricably linked in urban centers, yet human well-being is rarely a consideration when evaluating infrastructure options (Velarde, 2007). Due to its multifaceted nature, human well-being is defined for the purpose of this paper as it is by the World Health Organization (2004), meaning “A dynamic state of physical, mental and social wellness; a way of life which equips the individual to realize the full potential of his/her capabilities and to overcome and compensate for weaknesses; a lifestyle which recognizes the importance of nutrition, physical fitness, stress reduction, and self responsibility. Well-being has been viewed as the result of four key factors over which an individual has varying degrees of control: human biology, social and physical environment, health care organization (system), and lifestyle.” (p. 56). Much as “good” infrastructure is more complex than the mere existence of physical order where there had previously been none, “well-being” is more complicated than the mere absence of disease. This specific definition and basis for discussion is essential to elevating the consideration of the human effects of the built environment beyond superficial rhetoric to discourse with potential for ranging, real-life impact.

Consideration of well-being is essential because the cost of failing to address it is staggering. Poor wellbeing constitutes a complex combination of lack of preventative mental health care, inactivity, poor community cohesion, lack of economic mobility, and regular exposure to unpleasant or undesirable physical surroundings, and it's costing the USA upwards of \$90 billion dollars yearly in preventable health related expenses (Wang et al, 2011; Lederbogen et al, 2011; Russell-Mayhew et al, 2012). When impacts to livability and well-being fail to be considered during the design process, the results stand to negatively affect not just city budgets, but citizens themselves. Citizens who are generally self-identify as “healthy”, have regular exposure to nature, and have open, natural spaces in which to be active are less likely to burden overwhelmed healthcare budgets, commit crime, and otherwise negatively impact their community (Sullivan & Kuo, 1996; Coley et al, 1997; Idler & Benyamini, 1997; Kuo, 2003; Maller et al, 2006; Pinto et al, 2010). Additionally, connection to community and place expressed as social capital increases citizen ownership of their neighborhood, fostering a general social precedent of care-taking that the city would otherwise have to provide (Lyles-Chockley, 2009; Pinto et al, 2010; Blair et al, 2014). Citizen well-being provides a better quality of life for citizens and saves money for nearly all city departments, from crime prevention to reduced healthcare expense, which would lead one to view its consideration in city design as essential. But this is not yet the case, most prominently in the realm of water management infrastructure.

Despite correlations between well-being and green infrastructure design, literature on LID infrastructure primarily relates to storm water engineering and the effects alternative designs have on storm water flows to the exclusion of other emergent properties (Smith, 2007 & Maller et al, 2006). For example, the storm water load reduction has been the focus of research on stream daylighting, an emerging LID practice with potential for much wider reaching benefit

(Smith, 2007; Trice, 2013). One particular study from Germany explores the wellness benefits of urban waterways, and another mentions urban waterways as a category to explore and consider when building biophilic cities, but an extensive review suggests that these pieces remain the only two with a specified stated focus on well-being implications (Ulrich, 1993; Volker & Kistemann, 2013).

So while the realms of psychology, anthropology, and other areas of the humanities have expanded their focus on what constitutes and promotes well-being, city planning has yet to utilize this knowledge in the form of impactful assessment, policy, or infrastructure classification.

THE BUILT ENVIRONMENT AND WELL-BEING: WHAT WE KNOW, HOW WE'RE STUDYING IT, AND ITS LIMITED APPLICATION IN INFRASTRUCTURE PROJECTS

Advancements in the consideration of urban infrastructure's tertiary benefits to well-being are seen in the emergence of new fields of study and governmental assessments. Evaluative measures such as the Ecosystem Services Model, Environmental Impact Statements (EIS), Environmental Impact Assessments (EIA), and Health Impact Assessments (HIA) have all added to the relevance and consideration of impacts on human well-being in the design and implementation of infrastructure. These attempts at considering holistic value have numerous flaws and, excepting HIA's, the assessments tend to focus on narrowly defined environmental provisioning benefits and still fail to consider a complex understanding of well-being (Clark & Canter, 1997). Additionally, when water management infrastructure is directly mentioned in these assessments, it typically refers to grey practices that seek solely to eliminate waterborne illness and contamination, with little to no consideration of additional constituents of well-being nor alternative LID designs (NEPA, 1978; IAIA, 1999; Lock, 2000; CDC, 2012).

The fields of therapeutic landscapes (Williams, 1998) and biophilia (Kellert & Wilson, 1993) are substantiating correlations between environment and human well-being, but even these seem to exempt certain forms of infrastructure from the discussion, particularly waterways and water management, potentially preventing an application of their established principles to LID and other less traditional designs (Kellert & Wilson, 1993; Ulrich, 1993; Velarde, 2007; Jaffe, 2010; Heerwagen, 2013). These cross-disciplinary measurements and studies are advancing our understanding of well-being and how our cities affect it, but these advancements thus far have been relegated by the field of city planning to cursory infrastructure considerations if considered at all as evidenced by a lack of standards, measurement, and required assessment, as detailed in this section.

The Ecosystem Services Model is an assessment designed for more adequate valuation of services provided by natural features, like the financial savings provided by air filtration from urban trees. The model has gained popularity, helping to give environmental preservation and restoration a place in policy and economic discussion, but many have leveled a series of criticisms as to its fundamental structure (Schroter et al, 2014). One of those criticisms is the presence of an inherent bias in favor of more easily quantifiable economic and engineering services, relegating cultural benefits to a literal, in the placement and weakened links illustrated on the foundational Millennium Ecosystem Assessment (MEA) histogram, and figurative lower level of value, therefore failing to adequately account for essential constructs of human well-being (Helman, 2001; Schroter et al, 2014). The ubiquitous nature of the model in policy and academia circles and its failure to holistically account for “value” further exemplifies the absence of literature exploring potential simultaneous benefits, financial and otherwise, that urban natural systems may have for human well-being.

Environmental Impact Assessments (EIA) are utilized around the world to assess the potential effects, both environmental and social, of government and private policies and plans, and suggested courses of action for mitigation of potentially detrimental effects (IAIA, 1999). In the USA, these assessments are generally voluntary, excepting a handful of National Environmental Policy Act (NEPA) designated practices and fields, and serves only as a precursor to an Environmental Impact Statement (EIS), which provides a type of cost-benefit analysis of environmental effects (NEPA, 1978). While the environment affects people's well-being in multivariate ways, only potentially catastrophic physical health detriments, like carcinogen accumulation in drinking water, are a part of these assessments, leaving the promotion of health and interconnected attributes affecting well-being out of the discussion. An environment segmented, or not considered in its totality, can create difficulty in drawing connections, since the connections between individual constituents are inherently absent. This coupled with the lack of required action in response to these assessments reduces their potential benefit.

As health indicators in the USA, like preventative disease rates, have worsened, governments have sought to address the issue with a number of initiatives, including the establishment of a Health Impact Assessments (HIA) (Lock, 2000). HIA's study a number of cross-disciplinary health factors that a proposed policy or plan may potentially effect, forcing consideration of public health in traditionally non-health related fields, like urban planning (Lock, 2000). While they show promise, creating a place holder for well-being when evaluating projects shaping the built environment, HIA's are not a required evaluation and remain inconsistent in their considerations and measurements (Lock, 2000).

As urban populations increase, the focus in literature on the interdependency of humans and nature continues to expand. We are living in concentrated and concrete surroundings, and

many planners and architects are trying to “re-connect” the populace with local ecology by bringing nature in its many forms into the urban realm (Benedict et al, 2002). To this end, well-being research fields that encompass psychology, sociology, and public health are unearthing a rich and extensive connection between place and health (Sullivan & Kuo, 1996; Coley et al, 1997; Idler & Benyamini, 1997; Kuo, 2003; Maller et al, 2006; Pinto et al, 2010). Research into “therapeutic landscapes” has substantiated the benefit of human access to natural landscapes, but most of these landscapes are categorized into narrowly defined green Infrastructure, focusing on trees and foliage with little to no mention of waterways or water management, ultimately limiting the scope of ties between well-being and the built urban environment (Williams, 2007; Velarde, 2007). Literature from the field of Biophilia, a relatively new area of research into human connection to nature and impacts on wellbeing, contains several sources that refer to the potential human health implications of waterways, but do not go beyond the suggestions into actual categorical data (Jaffe, 2010; Heerwagen, 2013). The benefits to health indicators, activity levels, property values, and regulatory cost reduction obtained from urban trees and foliage have already been explored in depth, but again, waterways have not been a focus of this research (Jaffe, 2010; Heerwagen, 2013). Urban environments have been shown to increase stress levels, which has been linked to adverse health outcomes, but access to nature and urban parks, exercising in natural areas, and integrated design that incorporates human impact as well as engineering utility in the planning process have all been shown to hold promise for improving human well-being in urban centers, leaving one to see potential; in expanding these studies to LID (DeLongis, 1988; Pretty et al, 2005; Garde, 2008; Jaffe 2010; Lederbogen et al, 2011; Heerwagen, 2013).

Despite their potential to inform the planning realm, these fields of study do not appear to be adequately considered when creating and evaluating infrastructure projects. Biophilia is still primarily utilized by more forward thinking segments of the private sector, i.e. Google, who are utilizing this research to promote worker well-being in the design and development of their offices (Pearson, 2013). And water management, with LID designs that are already hard to classify and lacking in equal consideration to their green counterparts in other infrastructure classes, remains a cursory consideration, further stalling the evolution of these infrastructure designs and practices. HIA's are a step towards cementing well-being into the city planning process, but these and other assessments are still generally optional and wrought with inconsistency (Lock, 2000).

Without well-being, the true cost and value of infrastructure projects remains elusive, particularly innovative LID. Stream daylighting, a newer concept showing promise in both reducing combined sewer overflows (CSO's) and providing therapeutic open spaces for city dwellers, is an example of a promising practice with potential for broader application if the value of well-being is incorporated into assessment of urban policy and design.

EXAMPLE OF MISSED POTENTIAL: STREAM DAYLIGHTING

Stream daylighting is the “relatively new approach of unearthing and restoring streams in urban centers that have been paved over, diverted, and buried deep beneath the landscape”(Trice, 2013, p. 4). Most existing daylighting projects are designed to accommodate 100-year peak storm flows, and of case studies examined for a report commissioned by the city of San Francisco, the majority of existing projects have proven “successful” in flood reduction, reducing erosion, improving species diversity, restoring habitat connectivity, and significantly

reducing storm water flow (Smith, 2007). Stream daylighting has mostly been examined for strictly storm water load reduction benefits, though potential pollutant load reductions and economic savings appear promising (Conradin & Buchli, 2005; Smith, 2007). Daylighting has been shown to have implications on reducing water treatment costs by preventing CSO's via reduced loads in mixed wastewater pipes and reducing expenditure on flood mitigation (Conradin & Buchli, 2005; Trice, 2013). The extent of the potential of this practice for improving city infrastructure and open space has led to implementation of an entire stream daylighting program in Zurich, Switzerland's largest city (Conradin & Buchli, 2005). The depaving that occurs through the daylighting process holds additional promise for reducing costs associated with the urban heat island effect, or increased temperatures in city centers and subsequent environmental costs caused by rapidly heating urban surfaces (Kim, 1992; Conradin & Buchli, 2005; Trice, 2013). A case study of the first published research to examine the health benefits

EXPLORING WELL-BEING - LESSONS FROM VOLKER & KISTEMANN

Among the first studies to assess the potential well-being benefits of urban blue spaces was conducted by Volker & Kistemann (Volker & Kistemann, 2013). Researchers used both open-ended, standardized, and qualitative written surveys coupled with non-standardized observation to examine the effects of visiting waterfront promenades in two cities in Germany. Using a two-dimensional matrix containing characteristics of place and ontological dimensions, they were able to analyze their primary data using existing research and philosophy derived from the realm of Therapeutic Landscapes. The study compiled a tentative understanding of salutogenic, or health promoting, effects, like reduction of stress, increased physical activity, connection to place, and community cohesion.

Water features created space that attracted people to socialize, engage in physical activity like strolling and cycling, come down from their daily stresses, and connect more deeply with their community and city (Volker & Kistemann, 2013). The study has a number of flaws, but provides impetus for further exploration.

To apply a similar study in Portland at the project on Tryon Creek, secondary data would be valuable as supplement to further analyses and for the creation of economically quantifiable benefits. For example, resident surveys could be analyzed alongside average vacancy rates for these properties in comparison to similarly priced apartments nearby. This would be valuable since, when controlling for financial variables, connection to place would likely lead to longer tenancy and therefore reduced costs related to turn-over.

Additionally, specific physical and mental primary data could be obtained from a representative pool of residents and a control group from nearby neighborhoods. A simple heart rate monitor could assess research confirmed heart rate responses to potential stress reduction. A log of sick days from work and hospital visits could be compared, and any reduction of healthcare financial burden could be assessed.

The work from Volker & Kistemann provides groundwork for expansion, and the recommendations above could deepen our understanding of the benefits urban blue can provide.

of Urban Blue spaces, and recommendations for research expansion, are detailed in the informational box in the right sidebar of this section. Financial benefits and comparability are summarized well in the following excerpt from the study by Smith (2007):

“Though the costs of stream daylighting projects vary widely by geographic region, project scope, and degree of community or volunteer support, a few general estimates can be found in the literature. One source estimates \$100 per square foot (Webster 2007); others claim that stream daylighting generally costs \$1,000 per linear foot, or \$5.28 million per mile (Pinkham 2000). However, average cost in SF study per linear foot ranged from under \$40 to over \$3,000. For \$394 per linear foot; however, sheer replacement neither mitigates combined sewer overflows nor provides additional benefits beyond wastewater conveyance. Alternatively, constructing more storage structures might equate to about \$1,325 per linear foot, assuming 200 miles of sewers in the city and a \$1.4 billion cost to construct San Francisco’s transport-storage network in the 1970s. These cost alternatives indicate that daylighting can be cost-comparable with conventional, infrastructure- and material-intensive engineering solutions”(p. 8).

Stream daylighting harnesses ecological features and “excess” water to restore balance to nearby waterways and provide wellness-promoting access to nature for citizens (Trice, 2013). With evaluative constructs that emphasize “mitigation” and “management” rather than “utilization” and “promotion”, designs like this are hard to classify and fit into traditional practices and views. Tryon creek, a recently daylit stream in Portland, OR, faced classification complications in its creation, with developers and planners piecing together funds for stream restoration, endangered species protection, and more in order to justify project implementation (Blum, 2008; Headwaters at Tryon Creek, 2014). The project reduced speeds on neighboring streets, increased home values, expanded open space for citizens to be active, and the incorporated apartments attract a diverse range of citizens seeking access to its newly restored

natural surroundings (Blum, 2008). Livability and its subsequent benefits to well-being were of huge benefit to this project - a benefit that remains absent from economic valuation of the site by both the city and developers (Blum, 2008; “Daylighting in the Tryon Creek Watershed”, 2013). Rigid design standards and classifications that lack well-being as core evaluative measures appear to prevent adequate consideration of daylighting, since those broad ranging benefits in addition to storm water management are central to the design, setting them apart and potentially above traditional design.

This single-serve optimization paradigm, which focuses goals on optimizing one metric at a time, directs conventional water infrastructure towards designs that are created as if they will exist in simplified systems of inputs and outputs, with no consideration of their context within complex, interrelated systems (Haimes et al, 1975). In these models, simply meeting engineering benchmarks, like storm water load reduction or reduced contaminant concentrations, denotes success, regardless of additional impacts beyond these measures. In order to fully ascertain the value of stream daylighting and other similar designs, which have broader potential benefits within the context of their surroundings, there needs to be a multiple-benefit appraisal. Ecological accounting and multiple objective analysis may be conceptual starting points, as they proposes measuring emergent benefits and traditional benefits as a whole, seeking to optimize not just one parameter, but all parameters in context with one another (Haimes et al, 1975; Birkin, 2003). This kind of evaluation could advance ecologically inspired infrastructure by altering the goals of urban water management. Rather than highest optimization of one variable, future designs could seek adequate optimization of a web of variables. In additional to incomplete measurements of its value, stream daylighting has also failed to receive substantial literature examination, particularly in the USA, with most water management

literature focused on traditional practices with strictly water quality and load reduction the core evaluative measures (Mays & Tung, 1992; Baumann et al, 1997; Grigg, 2005). As discussed in the literature, design that integrates engineering and livability benefits may provide financially substantial reductions in negative health indicators while creating more desirable urban living spaces, suggesting that stream daylighting may be of highest and best use when utilized and studied holistically, or incorporating the value of its impacts beyond water quality and load reduction utility (Girling & Kellet, 2002; Garde, 2008). But paradigmatic limitations imposed by the lack of holistic consideration in traditional infrastructure are even more pronounced in the less considered realm of LID, where lack of clear classification, obdurate protocol, and preference for cost effective standardized production combine to stifle innovative design (Hommels, 2005). Similar ecologically based designs are competitive and comparable to traditional practices, but require rethinking and traditional land use trade-offs that may prevent their adequate consideration (Girling & Kellet, 2002).

Without holistic, cross-disciplinary measurement standards and further research into water management practices that influence these, stream daylighting may remain on the fringe of planning for the foreseeable future.

MOVING LID FORWARD: ADDRESSING BARRIERS

Rather than just touting potential benefit, deconstructing current barriers to emerging LID designs is essential to operationalizing progress towards more accurate and comprehensive assessment, design, and policy. This section lists and explains those barriers, whose existence is primarily established in preceding sections.

Barriers tend to fall into three categories: cultural, ideological, and physical. Specific barriers include but are not limited to the difficulty of measuring and calculating a value for something heretofore intangible, a culture of individual burden presupposing governmental “interventionism”, falsely held assumptions regarding sanitation of open waterways in city centers, the lack of clear classification for LID practices such as stream daylighting, subsequent difficulty in accessing funding for these projects, cross-departmental barriers caused by bureaucratic governmental segregation, and physical barriers, such as existing hardscapes, coupled with ideological barriers, like the obduracy of traditional techniques and protocol in city planning.

Many of these barriers are rooted in historical motivations, biases, and landscapes still largely shaped by infrastructure of past generations. Just as health and well-being are sciences that developed later in the historical timeline of cities, from germ theory only beginning to inform wastewater systems of the 1900’s to therapeutic landscapes only just now on the radar for the design of built environments, so has their quantification and consideration lagged behind more easily tangible and quantifiable measures (Melosi, 2000; Schroter et al, 2014). There is existing criticism of our collective failure to consider inherently human attributes and effects, as seen in the discussion of foundational bias in the Ecosystem Services Model that lessens “cultural” values in comparison to currently measureable resource and economic values (Schroter et al, 2014). This lack of consideration may lead to a minimized application of the complex concept of well-being in the realm of urban planning, with noted absence in the planning of waste and storm water systems.

Historical bias against greater government involvement in the design and management of storm and waste water, particularly against the enactment of programs with potential cross-

departmental reach, appears to be rooted in pre-colonial self reliance and inherent distrust in governmental management and taxation that entered the collective unconscious of the Americas around the time of the Revolutionary War (Wills, 1999). Designs like stream daylighting cannot be considered within a holistic framework without accompanying questions as to the “role” and “size” of government – is it the place of the government to seek both promotion of well-being *and* reduction of storm water loads? These doubts are coupled with assumptions of de facto urban waterway contamination arising from unsanitary conditions present during the defining rise of cities in 19th century America, a time when the absence of collective management led to the pooling of waste and storm water and the spread of disease (Tarr, 1996). While presumed contamination is based more on circumstances falsely equivocated to current cities, modern failures can give credence to concerns, as combined sewer systems regularly contaminate downstream waterways with human waste during larger storm water events, and can occur with upwards of weekly regularity (Riverkeeper, 2014).

While governmental doubt and sanitation concerns may lead to barriers in raising public and therefore political support for innovative LID policy and design, traditional land use and existing form may also cause implementation complications. Stream daylighting, for example, often requires de-paving large expanses of existing specifically purposed asphalt, and the practice is not clearly classified under current waste and storm water management (Trice, 2013). All new and updated infrastructure has potential to alter landscape and land use patterns, but traditional designs tend to coincide with traditional and existing landscapes and codes while new, ecologically symbiotic LID approaches may require alterations to traditionally impervious and grey city centers. When these policies, codes, and inflexible protocols developed around existing landscapes butt up against innovative designs that re-think traditional techniques, the

rigidity of urban planning bureaucracy prevents consideration of forward thinking practices (Hommels, 2005). When funding is tied to programs arising from these policies, alternative designs are destined to fail in securing streams of investment needed for implementation..

Beyond the systematic obduracy of planning paradigms, stringently segregated city departments, in name, staffing, and most importantly, budget, represent a major barrier to the implementation of innovative LID infrastructure. In the USA, city governmental departments are given capped budgets, with departments essentially in competition with one another for limited percentages of city funds. This climate of needing to justify expenditure would seem to deter cross-departmental conversation and planning, as ensuring your piece of the funding pie would discourage the splitting of tallied costs on shared projects. Introduce infrastructure that is not only cross-departmental in nature, but lacks clear classification required to allocate funds? Why would any department risk reduced yearly budgets to implement infrastructure that is paradigmatically unproven and budgetarily fuzzy? This failure to adequately combine departments when addressing problems stops conversation and stalls innovation, preventing new and creative designs from being discussed, let alone implemented.

The barriers to better water management infrastructure are extensive, but the adoption of holistic economic valuation offers opportunity to address them. Historically and presently, money and power have shaped our worlds and our city landscapes (Melosi, 2000; Hommels, 2005). Private industry, from railroads to piped water, have built where they saw potential for investment return, and cities have intervened only when circumstance urged action and taxation could be justified adequately to citizens. By accounting for the potential benefits to well-being that innovative, ecologically symbiotic LID practices provide, the true economic value makes clear how advantageous investment in these practices can be. Given financial backing, these

milieu, human health, and ecologically beneficial designs become *smart investments*, translating the benefit into a financial language city bureaucracy and private industry understand and care about.

CONCLUSIONS

As seen in the quantifiable benefits nature and green space have on the populace and the associated costs poor citizen well-being place upon cities and private industry, creating more holistic valuation metrics, particularly those that account for well-being benefits, stand to aid the advancement of affordable and ecologically sound LID that is less established than traditional techniques. Innovative LID has substantial financial savings potential and the translation of a previously considered “soft” metric to a monetary language relevant to structures of power creates a means of seizing that potential. Historically, where money and power could be gained, investment was made. If precedents are to be believed, holistic financial metrics stand to produce similar investment. Full accounting of emergent properties, particularly those relating to well-being, has potential to quantifiably express the benefits of forward thinking water management design, justifying potential investment in these practices to citizens, policy makers, and the private sector. Given metrics that more adequately quantify benefits provided to citizens and industry by livability and access to nature, and the returns contented and active citizens provide to cities and developers, may help bring “fringe” LID designs to the mainstream by making them more economically and politically feasible.

Accounting for well-being may also help spur the comparatively stalled conceptual evolution of water management infrastructure, while aiding cities in making more informed decisions regarding future infrastructure options.

If we fail to create clear economic quantification and assessment metrics for our expanding understanding of well-being, we stand to suffer a number of negative consequences. Design to nowhere, or “Island” Urban Planning, a term created for this paper, results from overly specified design and investment that fails to place itself in context, creating pockets of well-used space and infrastructure with “dead zones” in between that ultimately detract from advancement of the city and industry as a whole, as a building or space is only as valuable as its immediate surroundings. When you place a storm water planter here or a retention basin there without consideration of their connected nature as a network of inter-related and supportive infrastructure, there is a failure to maximize the benefits of constituent parts. An example of this failure and its negation of potential benefits is designing and building a phenomenal park, but locating this park across a highway from the neighborhood it seeks to serve. Without consideration for access, surroundings, and broader connections, the park goes unused – the space and investment ultimately wasted.

Expanding avoidable costs caused by failing to account for the healthcare, crime, etc. cost reductions associated with designs that have potential to improve livability and therefore well-being threatens the sustainability of the budgets of all urbanized places. With an increasingly urbanized world and large literature-supported economic, environmental, and health implications related to populace well being, livability can no longer be considered an accouterment in urban spaces – it is budgetarily essential. Lack of an inclusive long-term cost-benefit analysis also threatens best-practice implementation, preventing cities and citizens from making adequately vetted decisions related to urban design and infrastructure. If we leave bureaucratic governmental segregation unaddressed, we stand to stifle cross pollination and creation of more creative, innovative solutions to a whole host of urban ills.

Dogmatic protocol is also more likely to go unchallenged, and highest and best use infrastructure will potentially remain unattainable.

Realistically, to advance LID practices using holistic evaluative measures, more primary research and establishment of consistent metrics and LID specific classification is needed. Once an economic measurement of comprehensive human well-being is established and regularly applied, a holistic and more accurate understanding of LID infrastructure costs and benefits can be obtained, supporting the promotion and implementation of these designs.

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